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ERRAC Roadmap. Towards 2030: energy, noise and vibration European railway roadmaps

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Abstract

The European Rail Research Advisory Council (ERRAC) as a European Technology Platform and an advisory body to the European Commission is advising on the research needs of European rail stakeholders. From 2009 to 2012, ERRAC focuses on concrete and detailed roadmaps on common European R&D to implement the Strategic Rail Research Agenda. The Energy roadmap, the noise and vibrations roadmap are managed by the ERRAC Roadmap project WP1 – The Greening of rail transport; they define how to focus research efforts of the European railway industry in order to face increased emphasis on energy efficiency, environmental impact, design and the need to prepare for changes, reduced availability (and further disappearing) of fossil fuels.

This WP is leaded by Christophe Chéron, SNCF, co-leaded by Manfred Walter, Knorr Bremse AG, gathers stakeholders from railway operators, industry and academic research and universities.

The Energy roadmap raised that the use of energy by the European railway sector is efficient (compared to others modes), but even for railways, savings are unavoidable, as progressing towards a free carbon economy.

So the research efforts should consider:

- The development of the regeneration of energy (re-use of kinetic (braking) energy) through the smart grids concepts, managed in a system view or infrastructure or by sub-systems.
- Hybridisation of energy for diesel rolling stock.
- Implementation of storing systems (batteries, supercaps, flywheels).
- Energy efficient operation management (efficient driving, fluidification, etc.).
- Lighter rolling stock, management of the auxiliaries' consumption, next generation of power semi-conductor.

The noise and vibration roadmaps raised the following mainlines:

- Keeping the acoustic performance of the system (train and infrastructure) throughout its whole life.
- A new breakthrough in noise reduction – how to succeed minus 5-10 dB or more?
- Sustainable sound quality.
- Ground borne vibration: towards a better knowledge for control.

Keywords: Energy; roadmap; Europe; railway; noise; vibration

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1. Introduction

The European Rail Research Advisory Council (ERRAC) as a European Technology Platform and an advisory body to the European Commission representing Member States and all European stakeholders is advising on the research needs of European rail stakeholders. From 2009 to 2012, ERRAC focuses on concrete and detailed roadmaps on common European R&D to implement the Strategic Rail Research Agenda, whose last version was published in 23007.

The Energy roadmap (carried out in the WP1- The Greening of rail transport of ERRAC Roadmap) is drawing the roadmaps for research activities, dedicated to the management of energy in the railway domain to go towards carbon free and resource efficient railway for sustainable mobility and transport.

The noise and vibration roadmap (carried out in the same WP1) is drawing the roadmaps for research activities dedicated to noise and vibration in the railway domain, in order to, in a medium term view, integrate naturally all relevant processes of the railway, offering sustainable and practical solutions, implementation using a toolbox of various innovative and homologated techniques and in a long term view, strive towards noise and vibrations no longer being considered a problem for the railways and its neighbours – meaning that noise levels are socially and economically acceptable and allow for 24-hour passenger and goods operations.

2. ERRAC energy roadmap

2.1. Targets and Goals of Research

Climate protection

- By 2030 the European railways will reduce their specific average CO2 emissions from train operation[†] by 50% compared to base year 1990; measured per passenger-km (passenger service) and gross tonne-km (freight service).
- In addition, by 2030 the European railways will not exceed the total CO2 emission level from train operation in absolute terms even with projected traffic growth compared to base year 1990.
- The European railways will strive towards carbon-free train operation by 2050 and provide society with a climate neutral transport alternative.[‡].

Energy efficiency

- By 2030 the European railways will reduce their specific final energy consumption from train operation[§] by 30% compared to the base year 1990; measured per passenger-km (passenger service) and gross tonne-km (freight service).
- The European railways will strive towards halving their specific final energy consumption from train operation by 2050 compared to the base year 1990; measured per passenger-km (passenger service) and gross tonne-km (freight service).

Exhaust emissions: Nitrogen oxides and Particulate Matter (PM10)

- In addition, by 2030 the European railways will reduce their total exhaust emissions of NOx and PM10 by 40% in absolute terms even with projected traffic growth compared to base year 2005.
- The European railways will strive towards zero emission of nitrogen oxides (NOx) and particulate matter (PM10) from non-electric trains by 2050.

Nevertheless, we want to express:

- That the use of energy by the European railway sector is efficient (compared to others modes)

[†] 'CO_2 emissions from train operation' is defined by indicator 3 in the UIC leaflet 330, UIC 2008

[‡] Any moves towards a totally carbon-free rail sector ultimately depends on necessary changes in the electricity supply industry, which is outside of the direct control of the rail sector.

[§] 'Specific final energy consumption from train operation' is defined by indicator 1.1 in the UIC leaflet 330, UIC 2008

- That even for railways, the savings of energy are unavoidable
- That progressing towards a free carbon economy is unavoidable.

2.2. Priority area: system view

[General comments for roadmaps
CSA = Coordination Support Activity / R = Research / D = Development
Time horizon means Technical Maturity
1 ☆ = Low Priority / 2 ☆ = Medium Priority / 3 ☆ = High Priority]

Sector	Vision &need	Type of activity	Time horizon	Priority
Railway System	**Monitoring Systems** *Provision of detailed information about energy consumption in the railway system (by service type)*	R	2020	☆☆
Railway System	**Re-use of kinetic energy** *Improvement of technologies with basic systems being available* *Link to smart grids* *Reliability to be proven*	R	2020	☆☆☆
Railway System	**Smart Grids** [**] **and the multiplication of energy sources** *Development of techniques based on an economical potential assessment*	R & D	2030 Continuous research efforts required	☆☆☆

2.3. Priority area: rolling stock

Sector	Vision & need	Type of activity	Time horizon	Priority
Rolling Stock	**Lighter Trains** *Assessment of the technology transfer potentials from the aeronautic and automotive sector to the railway sector*	CSA	2015	☆☆☆
Rolling Stock	**Lighter Trains** *Weight reduction for the suburban and urban passenger services* *In due consideration of standardisation and regulation issues (e.g. crashworthiness)* *Design methodologies to be re-evaluated*	R & D	2020	☆☆☆
Rolling Stock	**Hybrid Traction** *Multiple power sources for traction in due consideration of RAMS*[††] *aspects for diesel applications* *Development of prototypes* *Energy Storage on-board* *Technologies to be carried out* *Engine stop at station*	Concluding research (R) activities required followed by (D)	2020 - 2030	☆☆☆

[**] Intelligent distribution and storage of energy within the railway system (comprising rolling stock, infrastructure, real estate etc.) with a potential interface to the public grid and the ability of timely balancing the energy flow

[††] RAMS = Reliability, Availability, Maintenance, Safety

Rolling Stock	**EE Auxiliaries** *Optimisation and development of intelligent management of auxiliaries (e.g. powering auxiliaries with kinetic energy)*	R	2020	☆☆
Rolling Stock	**Next generation of power semi-conductor** *Improvement of efficiency, weight, volume among others* *Standardisation (Common expressed request by the railway sector to the semi-conductor industry)*	R	2020 - 2030	☆☆

2.4. Priority area: infrastructure

Sector	Vision & need	Type of activity	Time horizon	Priority
Infrastructure	**Sector Smart Grids** *Development of techniques based on an economical potential assessment*	R	2030	☆☆☆
Infrastructure	**Advanced Traction Energy Supply** *Assessment of existing catenary materials and components – Potential analysis for optimisation*	CSA	2015	☆☆☆
Infrastructure	**Advanced Traction Energy Supply** *Increase of line voltage in order to decrease the losses* *New catenary materials*	R	2015 - 2020	☆☆☆
Infrastructure	**Infrastructure Sections without catenary** *Railway lines without catenary operated with particular adapted rolling stock (traction energy supply by pantograph and energy storage on board)*	R	2050	☆☆
Infrastructure	**Feeding kinetic energy back to the public grid** *Political approach and economic assessment*	R	2020	☆
Infrastructure	**Energy Storage in the infrastructure**	D	2020	☆

2.5. Priority area: railway operations

Sector	Vision & need	Type of activity	Time horizon	Priority
Operation	**Standardised EE Driving** *TecRec "EE Driving" (Stand-alone system) and TecRec "Drivers Desk"*	R	2015	☆☆
Operation	**Traffic Flow Management** *Holistic Approach towards traffic "fluidification"* *Specification of interfaces/ communication between IM and RU* *Real time traffic optimisation*	R	2020	☆☆☆
Operation	**Parked Trains Management** *Specification and Recommendations*	R	2015	☆☆☆

2.6. Priority area: hydrogen and fuel cell

Sector	Vision & need	Type of activity	Time horizon	Priority
Innovative Propulsion	**Innovative Propulsion** *Implementation of hydrogen fuel cell in due consideration of RAMS/LCC[‡‡] incl. the aspect of hydrogen production and storage*	D	2050	☆

[‡‡] Life Cycle Cost

3. ERRAC noise and vibration roadmap

3.1. Targets and Goals of Research

- By 2030 noise mitigation measures will be integrated naturally in all relevant processes of the railway, offering sustainable and practical solutions, implemented using a toolbox of various innovative and homologated techniques.
- The European railways will strive towards noise and vibrations no longer being considered a problem for the railways and its neighbours – meaning that noise levels are socially and economically acceptable and allow for 24-hour passenger and goods operations by 2050.

Based on many years of research and experience, the railway sector's noise control strategy is the following. A precondition, of course, is proper maintenance of the track.

Noise & vibration reduction strategy for the railway sector:

The main priorities are noise and vibration control at the source and in the transmission path and improvement of acoustic comfort in passenger vehicles. Noise control at line-side receiver locations has less priority as source and transmission measures are more effective.

Priority 1 - Noise & vibration control at source

This includes all sound and vibration generation and radiation from the vehicle and track, up to the boundary of the clearance gauge. It is by far the most efficient and cost-effective. Main topics are:

- Smooth wheels on smooth rails:

This is a prerequisite for low rolling noise and implies both low roughness of running surfaces and avoidance of irregularities including wheel flats. It implies that maintenance of wheels and rails needs to be optimal and that all components that affect roughness growth or surface deterioration should be optimised, including braking systems.

- Vehicles and tracks with low sound radiation:

For rolling noise, besides the surface roughness of wheel and rail, the vibration and radiation from the wheels and tracks offers potential for noise reduction through improved design and application of damper and shielding systems. For other sources including traction and cooling systems, and aerodynamic noise, source levels need to be reduced on the vehicle.

- Reducing the track contribution

The noise contribution from the track is known to be significant. Although design solutions to reduce it are known, they are often not applied in the initial design stage due to lack of information or incentives and are not included in regulation. Several dB and significant savings may be gained by correct application. Therefore strategies have to be developed to enable and stimulate this type of measure.

- Interior Noise

The interior acoustic noise level is currently acceptable. Designing the interior ambiance for passenger is the key issue in order to attract more passenger to railways in the same way as the automotive sector is performing.

Priority 2 - Noise & vibration control in the transmission path

All noise control measures beyond the clearance gauge are in the transmission path and include noise barriers, embankments and covering. Main issues for future research are

- Innovative noise barriers, especially innovative, landscape friendly and socially accepted design

3.2. Priority areas - Vision

Keeping the acoustic performance of the system (train and infrastructure) throughout its whole life

- Cost effectiveness of solutions for an implementation in commercial and operational solutions

The main actions to be taken are the following:

- Develop optimized, cost-efficient, and system integrated (from operational and maintenance point of view) solutions for rail grinding, track absorbers (and to a less extent wheel absorbers, the latter being more frequently implemented)
- Develop low cost disk braked freight bogies or single wheel set running gears

- Monitoring and maintenance of the system vehicle and infrastructure from a maintenance point of view

The main subjects to be addressed would be the following:

- Standardization of the monitoring devices and processing methods for pass by monitoring of vehicles, getting further insight in flat and roughness generation.
- Identification of wheel flats from their acoustical point of view and management of maintenance with the less possible incidence on the vehicle maintenance point of view
- Developing and standardizing operational monitoring systems for track (roughness and track decay rates) along with the associated operational measures for an affordable maintenance policy
- Developing the concepts and tools for economic maintenance of track taking into account the increased knowledge in roughness generation.

A new breakthrough in noise reduction - minus 5-10 dB or more!

- Rolling noise revisited

The fundamental thing to accomplish is to have smooth wheels running on smooth rails. Despite that considerable efforts have been devoted to this area in the recent decades there are still untapped potential for further progress:

- new wheel and rail materials / surface coatings (initial smoothness and low roughness growth)
- shielding - combination of low barriers and vehicle skirts
- more efficient rail and wheel dampers
- understanding more precisely roughness growth in combination with keeping the adhesion properties for traction and breaking
- more fundamental modelling on switches and crossings with developing time domain modelling
- efficient noise reduction methods for existing (steel) bridges
- construction principles for low noise wheels and track components

- More research on aerodynamic noise, generation, propagation and control - Improved prediction methods and design solutions for aero acoustics of high speed trains

- Target annoying noise, tonal noise - Further reduction for traction noise / equipment noise / screech / squeal

All kinds of tonal and squeal noise are considered very annoying and since these noise normally occur in densely populated areas a large number of people are affected. Eliminating such noise must be high on the agenda.

- New cooling concepts / thermal management / intelligent control to reduce cooling fan noise, in combination with further optimization of fans to ensure the effective implementation for the concepts developed
- Smart management of auxiliary systems during standstill in stations start and braking stages
- Electric braking to zero speed to avoid brake screech
- New brake pad materials / disc brake optimisation to avoid brake screech
- (Active) radial steering bogies to avoid curve squeal

- Indicators beyond the dB (A) level

Further work and standardisation is necessary on

- Choice of indicators
- Management strategies for the above situations

- A system approach for noise reduction

This statement holds for most aspects of railway noise – in particular where there is a vehicle-track interaction (rolling noise, squeal noise)

- Optimisation of vehicle/track design parameters to minimize rolling noise / squeal noise
- Standardization of noise sources definition for railway noise modelling
- Harmonisation of global modelling tools

- Demonstrator: Green Silent European Train & Track - Real train and track where green solutions are implemented and tested in operation

Improvement of interior acoustic comfort for passengers

- Define estimators and the associated scale enabling to relate the sound intensity to the discomfort/annoyance perceived for train's passengers
- Characterise the background interior noise to define which aspects sound comfortable and which aspects sound annoying or uncomfortable
- Define when sounds emerging from the background noise are perceived annoying or uncomfortable
- Define physical criteria allowing the specification of various types of sound experiences: representative of different types of trains or different areas within the train
- Express the relationship between the perception of vibration and sound in the overall subjective perception of comfort or discomfort
- Tools to evaluate the perceived acoustic comfort of users during design and pre-design phases.

Ground borne vibration and vibration induced noise: From better understanding of the phenomena to efficient vibration control

Efficient vibration reduction is generally based on three fundamental building blocks:

- Reliable prediction methods for choosing the optimum vibration mitigation techniques already at a very early stage in the planning process for new railway lines and for railway lines undergoing major reconstruction.
- Low vibration rolling stock and tailored vibration reduction technologies for hot-spots.
- Well-defined assessment criteria for noticeable vibrations in buildings and the closely related issue of low frequency vibration induced noise.

Compared to air-borne noise, knowledge of vibration from railways is far less advanced. This holds basically for all aspects, including most notably the generation mechanism, transmission in the ground and in buildings, and assessment of the impact on humans. Even very basic quantities like e.g. the threshold of perception of vibration by humans are the subject of controversial discussion. Sustainable vibration mitigation therefore has to start with a better understanding of the underlying phenomena.

So main domains for research are the following:

- Better understanding of the generation mechanisms
- Modelling
- Innovative vibration mitigation technologies
- Standards for the assessment of vibration
- Annoyance

- Clear responsibilities
- Improved communication strategy